Chemical, Biological, Radiological, and Nuclear Agents

Subjects: Others

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Combating chemical, biological, radiological, and nuclear (CBRN) threats with novel solutions reduces disasters and accident risks and, at the same time, aids sustainability.

CBRN agents hazards toxic industrial materials chemical warfare agents

1. Introduction

Excess amounts of hazardous substances in the environment may hinder the development of a sustainable world. Man-made disasters, natural catastrophes, heavy metals in industries, pesticides in agriculture, relying on non-renewable sources of energy, and even weather conditions are all factors that contribute to the distribution of hazards, which cause severe damage to humans and the environment. Land, soil, water, air, noise, and plastic/microplastic pollution put tremendous pressure on natural resources and the environment [1]. This situation can lead to spreading of diseases, and pathogens such as SARS-CoV-2, further facilitated by migrations [2][3].

Next to the long-term processes posing risks to the environment and human health are incidents caused by CBRN (chemical, biological, radioactive, and nuclear) agents. They can be created intentionally by man, by accident, or by natural sources. It should be added that CBRN hazards are often associated with a weapon of mass destruction [4], specifically when used in terrorist activities, warfighting, or ethnic conflicts [5]. History can provide several examples of incidents caused by CBRN agents. Radiological incidents are among the most disastrous, such as the Three Mile Island accident in 1979, the Chernobyl disaster in 1986, and the Fukushima Daiichi catastrophe in 2011 [6]. Other examples include the release of methyl isocyanate by a chemical plant in Bhopal, India, in 1984 [7]; an attack on the Tokyo subway in 1995 with sarin gas [8]; deliberate contamination of postal items with anthrax in the US Postal Service (New Jersey, 2001) [9]; melamine (a chemical usually used in plastics) used in milk in China, 2008 [10]; and the discovery of caustic, saline red mud (pH 12) that contained toxic trace metals beyond the acceptable levels in Hungary, Ajka (4 October 2010) [11]. Often, tragic catastrophes inspire the creation of legal regulations to counteract similar events. For instance, in Seveso, Italy, a minor chemical manufacturing plant accident occurred, leading to the residential population’s greatest exposure to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) [12]. The accident triggered some scientific studies and safety regulations in the industry. Seveso II is the name given to the EU industrial safety regulation. Currently, CBRN threats are the subject of numerous analyses in connection with the war in Ukraine [13], and the probability of releasing dangerous toxic industrial resources (chemical and radioactive) due to warfare is very high.

One solution to counter the threats is an ongoing necessity to create an array of innovative solutions for risk mitigation and defense against hazards. Innovation is understood as duplicable knowledge considered new in the context in which it is introduced and demonstrated [14]. It can be treated as an outcome, a process, and a mindset [15]. According to data presented by European CBRN Innovation for the Market Cluster—ENCIRLCE, innovations in CBRN involve over 1000 projects and activities (funded by, e.g., Horizon 2020, European Defence Agency, NATO, Directorate General for International Cooperation and Development—Centre of Excellence, Erasmus+, European Regional Development Fund) [16]. The topics of innovations include various aspects: CBRNe (CBRN + explosives) detection in containers [17], detection, identification, and monitoring of chemical hazards in the environment [18], reconnaissance in CBRNe incidents [19], CBRN personal protective clothing [20], laboratory capacities in Africa against COVID-19 and other epidemics, CBRN protection of critical infrastructure, and transportation of dangerous goods by road and rail [21].

In combating CBRN hazards, innovations play a pivotal role in supporting the development of a sustainable world, specifically the Sustainable Development Goals (SDG): to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity [22]. Therefore, in the context of the existing threats, as policies and actions should be concentrated on sustainability, it is vital to investigate the directions of the innovations. The investigation will contribute to the landscape of CBRN innovation. Presently, they are traced by leading organizations, such as the MASC-CBRN—an initiative funded by the European Commission (promotes the development of an integrated and comprehensive approach to CBRN events) [23], or CBRN Central, an expert portal on the latest news on homeland security and preparedness for CBRN and explosive (CBRNe) threats [24].

2. Overview of CBRN Agents

CBRN agents are classified into many areas. The most general classifications divide them into substances used for combat purposes and those used in industries as toxic industrial materials (TIMs). It should be noted that the term TIMs is not synonymous with industrial chemicals (TICs), as it also includes toxic industrial biologicals (TIBs) and toxic industrial radiologicals (TIRs) [25].

Chemical agents can be categorized as TICs and chemical warfare agents (CWAs). Toxic industrial chemicals (TICs) include sulfur dioxide (SO2), hydrogen cyanide (HCN), hydrogen sulfide (H2S), ammonia (NH3), and chlorine (Cl2) [26]. At the same time, chemical warfare agents (CWAs) encompass, for instance, cyclosarin (GF), VX (venomous agent X), tabun (GA), soman (GD), sarin (GB), and sulfur mustard (HD) [27]. Biological agents can be divided into categories A, B, and C. Category A agents are easily transmitted, resulting in high mortality, may cause public panic, and require extraordinary actions. Their examples are anthrax, smallpox, botulism, plague, tularemia, and viral hemorrhagic fevers. Category B agents are moderately easy to disseminate, result in moderate morbidity and low mortality rates, and require enhanced diagnostic capacity surveillance. They can be salmonella, typhus, or ricin. Category C agents are available everywhere, easy to produce and disseminate, and may result in high morbidity and mortality rates. They encompass the Nipah virus and hantavirus [28]. Regarding radiological agents, there are four major types of radiation: alpha (a relatively large subatomic particle—a helium nucleus, within a short range in the air, but it is potentially hazardous in the case of organism contamination); beta (relatively small subatomic particles consisting of electron/positron, within several meters range in the air); neutrons (connected to nuclear materials and the fission process, which are highly penetrating and vary in damage, depending on the energy of the neutrons); and gamma rays which penetrate intensely within a range of kilometers and consist of high-energy electromagnetic waves [29]. Apart from this general classification, there are other views. For instance, according to Bland (2009), chemical agents include nerve agents (organophosphorus compounds), blistering agents (vesicants), cyanides (also known as blood agents), pulmonary agents (choking or lung-damaging agents), incapacitants (mental and physical), toxic industrial chemicals (TICs), riot-controlled agents (RCAs, used by law enforcement agencies), and pharmaceuticals (illicit and commercial drugs). Within biological agents, there are bacteria, including chlamydia and rickettsia, viruses, fungi, and toxins, which can be derived from bacteria, fungi, plants, and animals (venom). Concerning radiological and nuclear hazards, Bland distinguishes four main types of radiation: alpha, beta, neutrons, and Gamma/X-ray radiation and notes that neutrons are usually only present during the nuclear process [30].

The classifications are not entirely clear because many substances that are warfare agents can also be used in industries and medicine, e.g., hydrogen cyanide (HCN), phosgene (COCl2), and botulinum toxin. In addition, some plant protection products have a high level of toxicity, e.g., sarin. Therefore, the essential division category is the purpose and method of using these hazardous substances, which can be described as “dual-use substances”. Regardless of intentional or accidental release, the characteristics above reveal the serious harms CBRN agents can cause to human health and the environment. This is due to the different persistence of a substance—it can disappear a relatively short time after exposure or remain in the environment for a longer time. The danger is also related to various routes humans can be exposed to CBRN agents, such as inhalation (gas, vapor, aerosol, droplets, or smoke), ingestion, skin (intact skin, inoculation—intentional break in the skin in order to introduce a CBRN agent, wounds), mucous membranes, or eyes [30].

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